Orion Pad Abort 1 Flight Test Overview

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Agenda

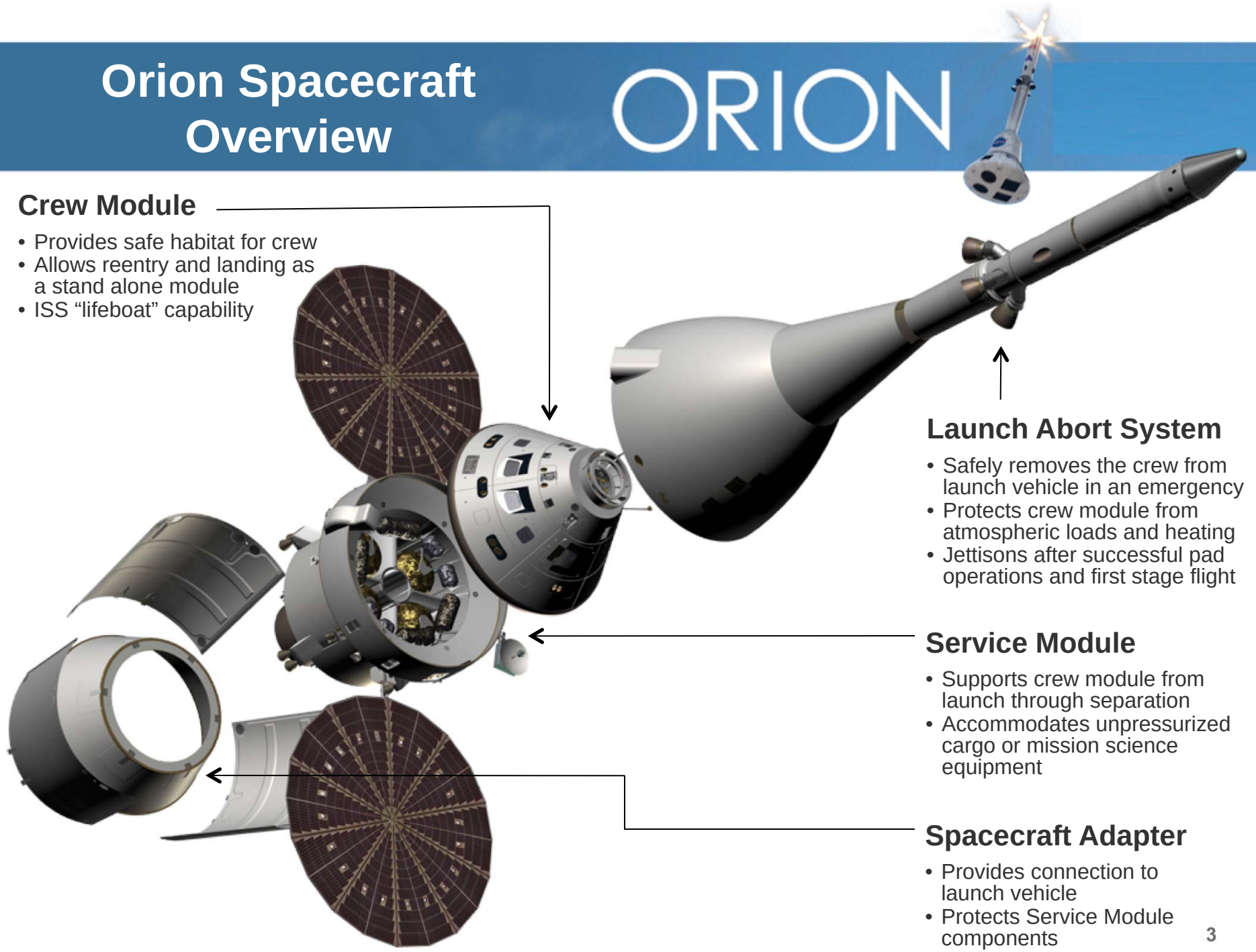
- **Introduction to Orion**
- **Pad Abort 1 Flight Test Overview**
- **Pad Abort 1 Vehicle Description**
  - Launch Abort System
  - Crew Module Simulator
- **Mission and Timeline**
- **Test Objectives**
- **Mission Success**
- **WSMR Range and Test Day Plan**

Orion Spacecraft Overview

ORION

Crew Module

- Provides safe habitat for crew
- Allows reentry and landing as a stand alone module
- ISS “lifeboat” capability



Launch Abort System

- Safely removes the crew from launch vehicle in an emergency
- Protects crew module from atmospheric loads and heating
- Jettisons after successful pad operations and first stage flight

Service Module

- Supports crew module from launch through separation
- Accommodates unpressurized cargo or mission science equipment

Spacecraft Adapter

- Provides connection to launch vehicle
- Protects Service Module components

Launch Abort System

ORION

Pad Abort 1 Test Overview

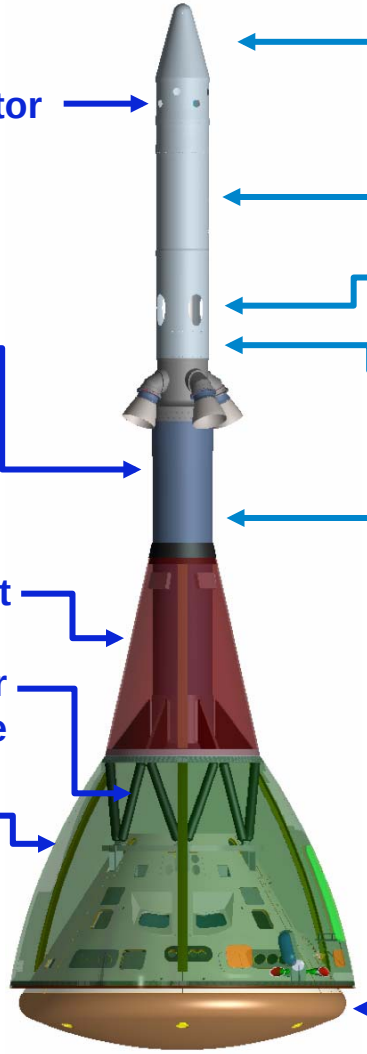
Test Summary	Early demonstration of launch abort system for pad abort.
Primary Objectives	♦ Demonstrate the capability of the Launch Abort System (LAS) to propel the Crew Module (CM) to a safe distance during a pad abort. ♦ Demonstrate the stability and control characteristics of the Launch Abort Vehicle (LAV) ♦ Demonstrate the performance of the Abort, Jettison, and Attitude Control Motors. ♦ Obtain LAS/CM interface structural loads and external acoustics data. ♦ Demonstrate the ability of the LAS to jettison from the CM. ♦ Demonstrate the ability of the Forward Bay Cover to jettison from the CM ♦ Demonstrate the parachute recovery system sequencing and performance
Test Configuration	
Launch Abort System (LAS)	Development LAS consisting of prototype motors, structures, and systems. DFI RDAUs, FADS
Crew Module (CM)	Boiler plate OML structure with Forward Bay and Cover, 1st generation parachutes, test avionics, flight representative mass properties, DFI pallets and RDAUs
Service Module (SM)	None / Unique separation ring used for interface between CM and launch pad
Spacecraft Adapter (SA)	None
Test Site	White Sands Missile Range
Landing Site	White Sands Missile Range

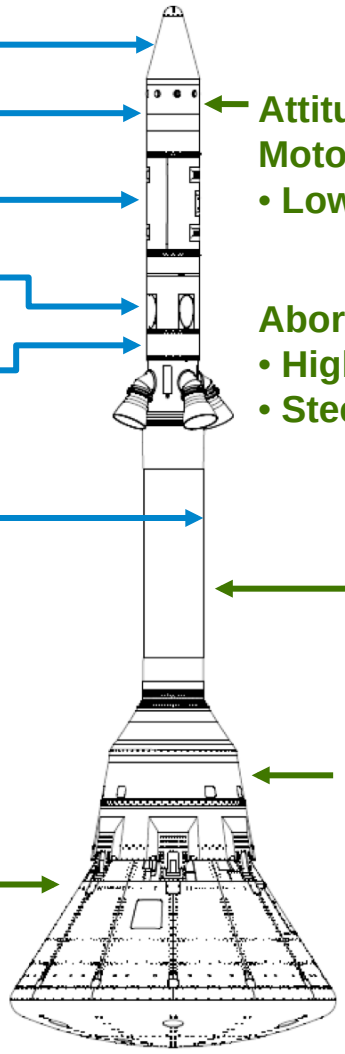
LAS Configuration Difference Summary

ORION PA1

Spacecraft Configuration

PA-1 Configuration





Attitude Control Motor
• Std Thrust

Abort Motor
• Low Thrust
• Titanium Manifold

LAS Fairing Assembly (LAS FA)

Fillet

AM Adapter Structure

Ogive

Crew Module (CM - LM)

Nose Cone

Attitude Control Motor
• 80%Thrust

Canard Interstage

Jettison Motor

Interstage

Raceway

Attitude Control Motor
• Low Thrust

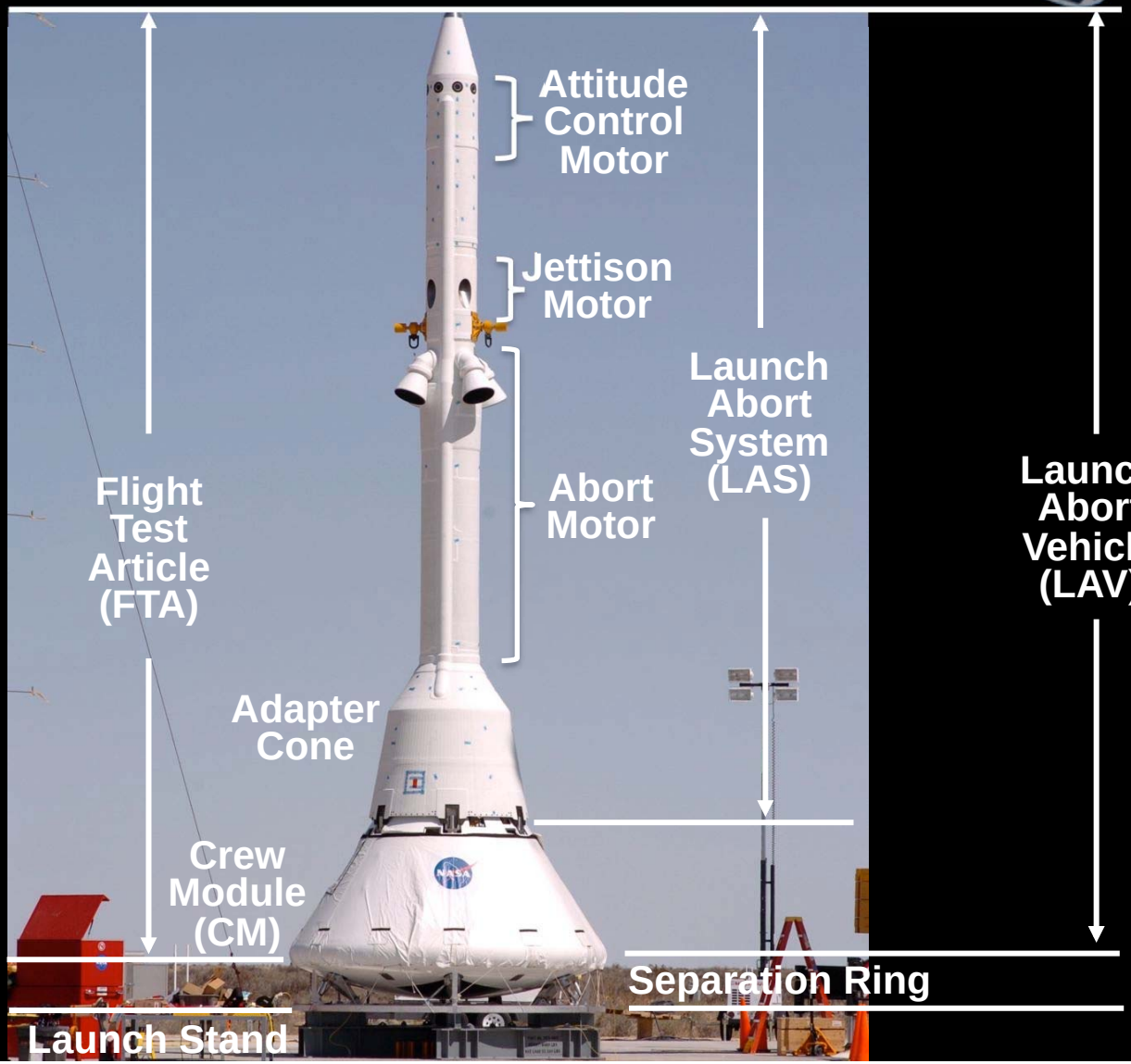
Abort Motor
• High Thrust
• Steel Manifold

Crew Module (CM - NASA)

Adapter Cone

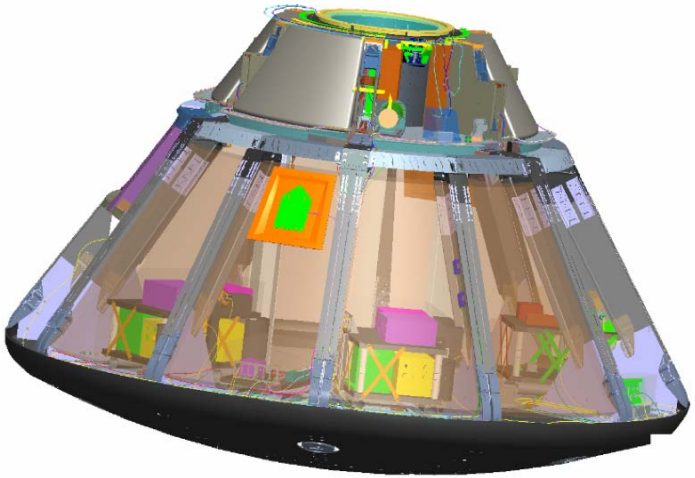
PA-1 Flight Test Article Overview

ORION PA1



Crew Module Configuration Summary

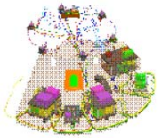
ORION PA1



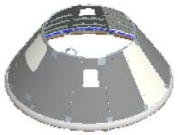
FWD BAY COVER INSTL

CPAS SYSTEMS INSTL & INTEGRATION FWD BAY

CM FWD BAY STRUCTURE ASSY



INTEGRATION PRIMARY STRUCTURE *(LAS R&R BRACKETS, AVIONICS, DFI, ANTENNAS, HARNESSES, THERMAL DUCTING, ACOUSTIC BLANKETS)*



SKIN INSTL

BULKHEAD FRAME ASSY

PRIMARY STRUCTURE FRAME ASSY

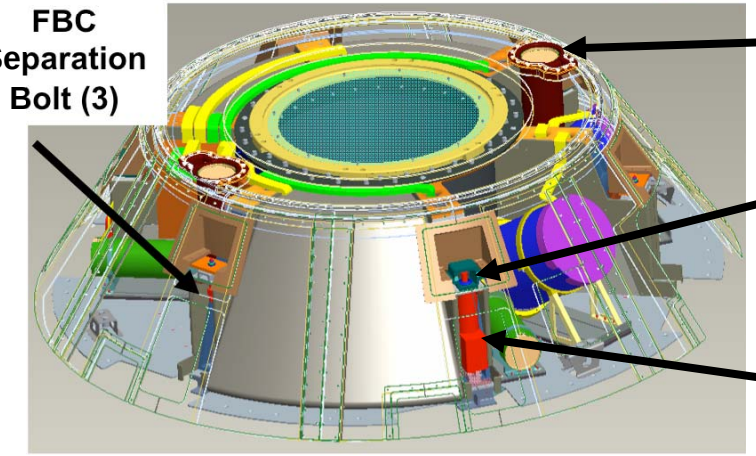
SHIELD STIFFENER ASSY

HEAT SHIELD SKIN

PA-1 crew module is a boilerplate design for abort flight test purposes only – Structure not optimized for spacecraft application.

Forward Bay Cover (FBC) Jettison Mechanisms

ORION PA1



- FBC Jettison Mechanisms provide the structural connections between the forward bay gussets and the FBC and the mechanism by which separation occurs
- Consists of 2 chute mortars, 3 Separation Bolts, and 3 Thrusters

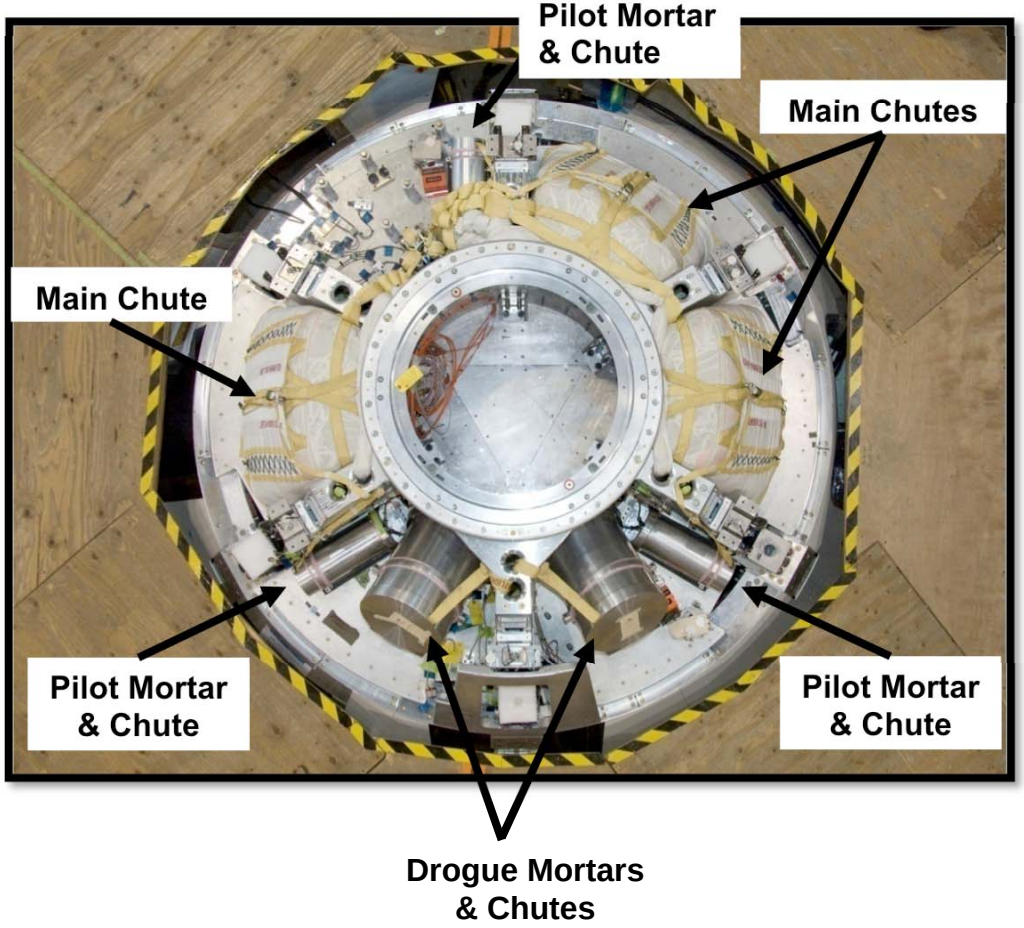
FBC Separation Bolt (3)

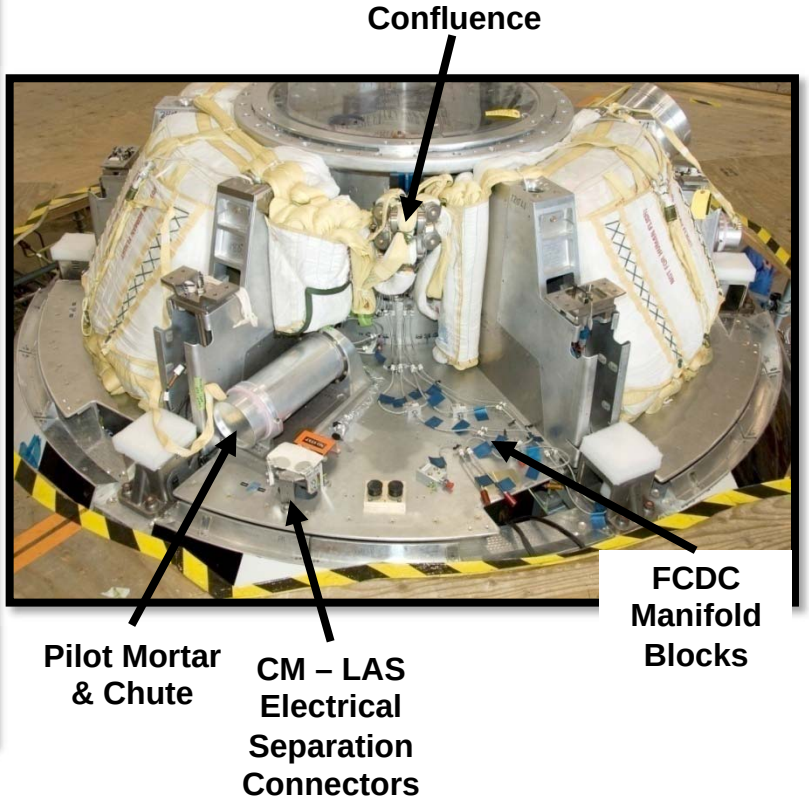
FBC Thruster (3)

FBC Parachute (2)

Forward Bay Parachutes

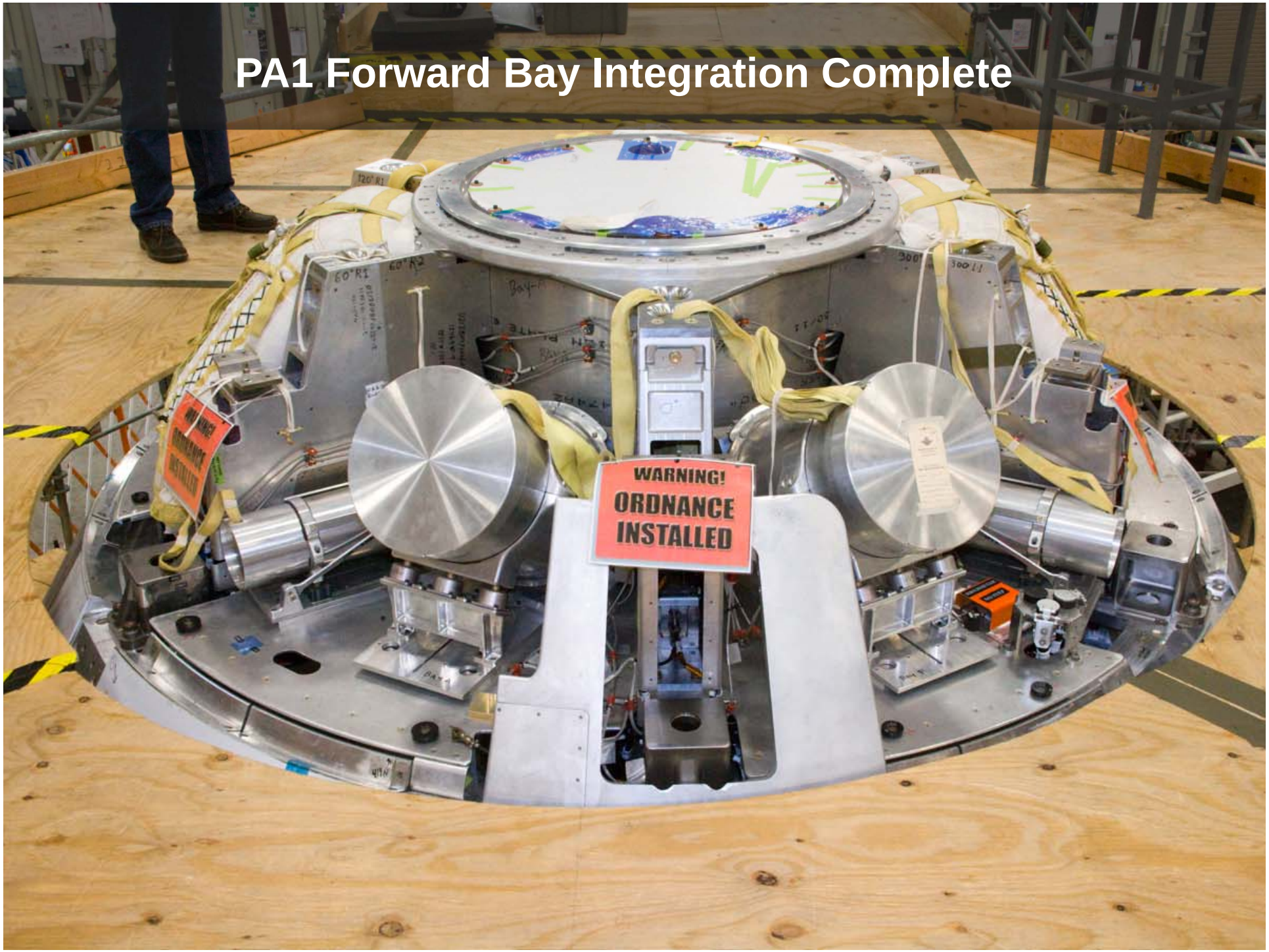
ORION PA1





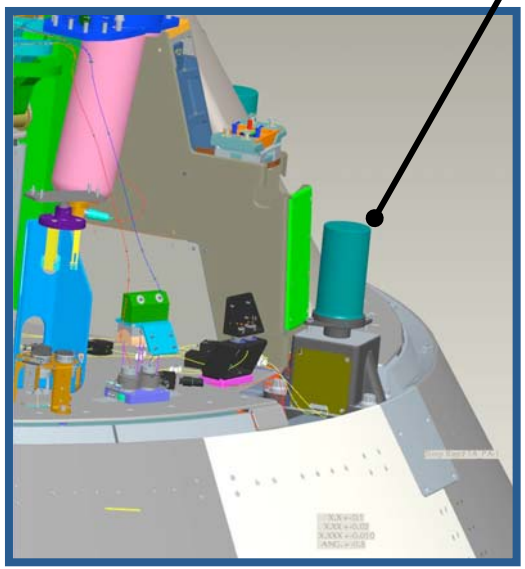
- Forward bay contains the CPAS Gen I chutes, the Forward Bay Cover R&R Mechanisms, and CM-LAS electrical Separation Connectors

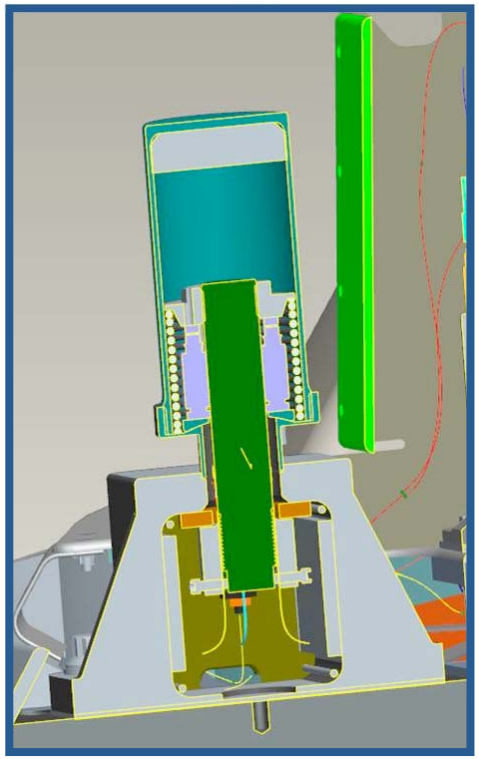
PA1 Forward Bay Integration Complete



LAS Retention & Release System

ORION PA1

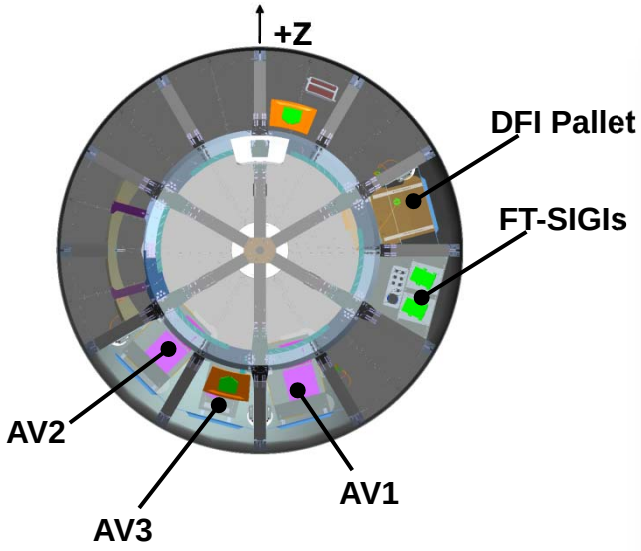


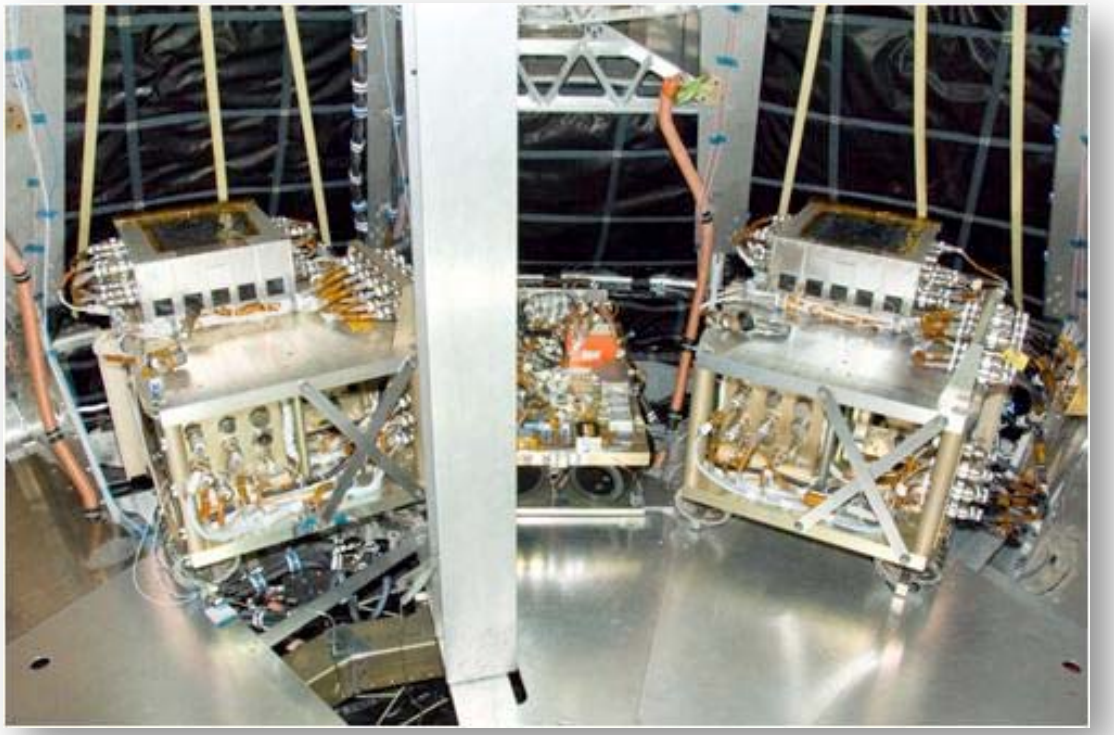


- LAS R&R system provides the structural connection between the CM and the LAS and the mechanism by which separation occurs
- 6 LAS R&R mechanisms mounted above the 6 primary longerons
- Each mechanism consists of frangible nuts (with containment) holding pre-tensioned studs from the LAS side, initiated with 2 booster cartridges each

CM Avionics and Avionics Pallets

ORION PA1

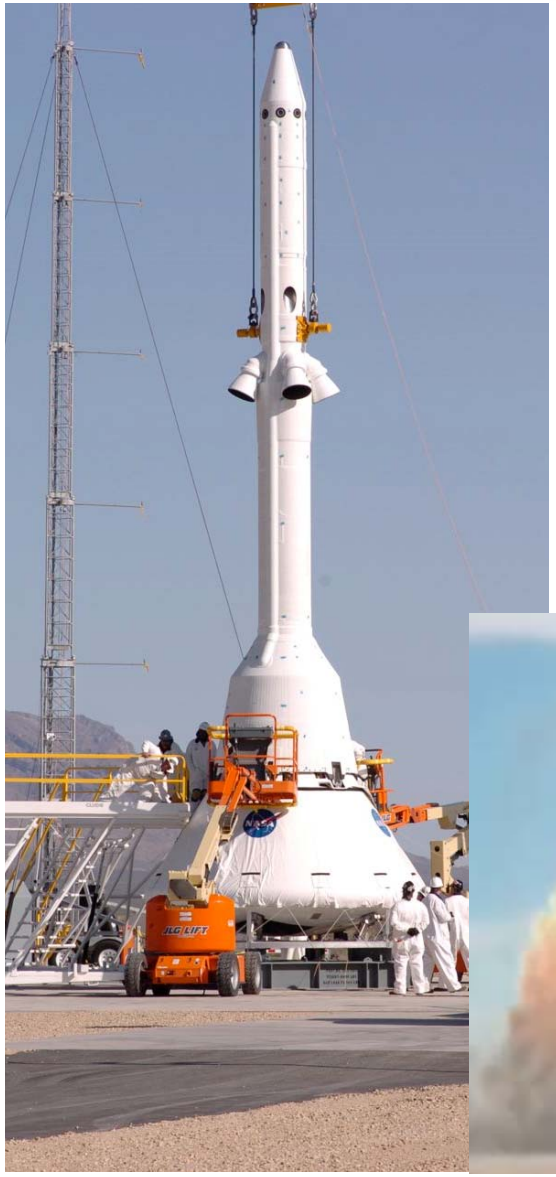


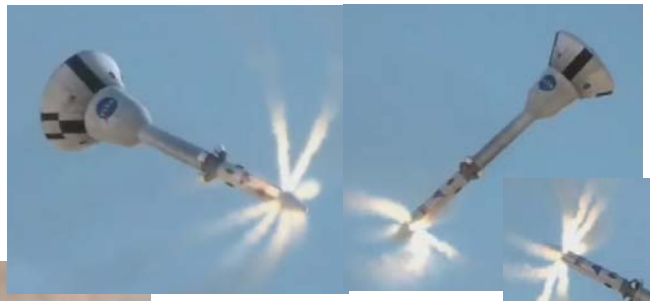


- Avionics system is a palletized design with dedicated racks and structurally dampened pallets
- Avionics is a dual-string system with redundancy allowing for continuous operation in the case of a single point failure

PA-1 Mission Overview

ORION PA1





LAV reorientation under ACM control

ACM controlling pitch & yaw during coast

LAS jettison

Abort motor & ACM ignition

Mission timeline:

Ignition = 0 s	End reorientation = 16 s
Abort motor burnout = 7 s	LAS jettison = 21 s
Begin reorientation = 10 s	LAS touchdown = 49 s

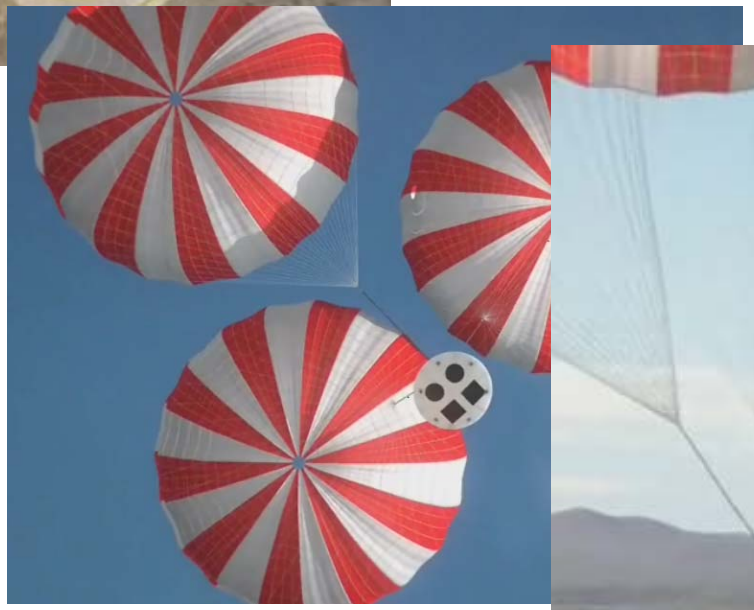
Crew Module Parachute Deployment and Descent

ORION PA1

Forward bay cover jettison

Drogue chute (23 ft diameter each) deployment

Main parachute (116 ft diameter each) deployment



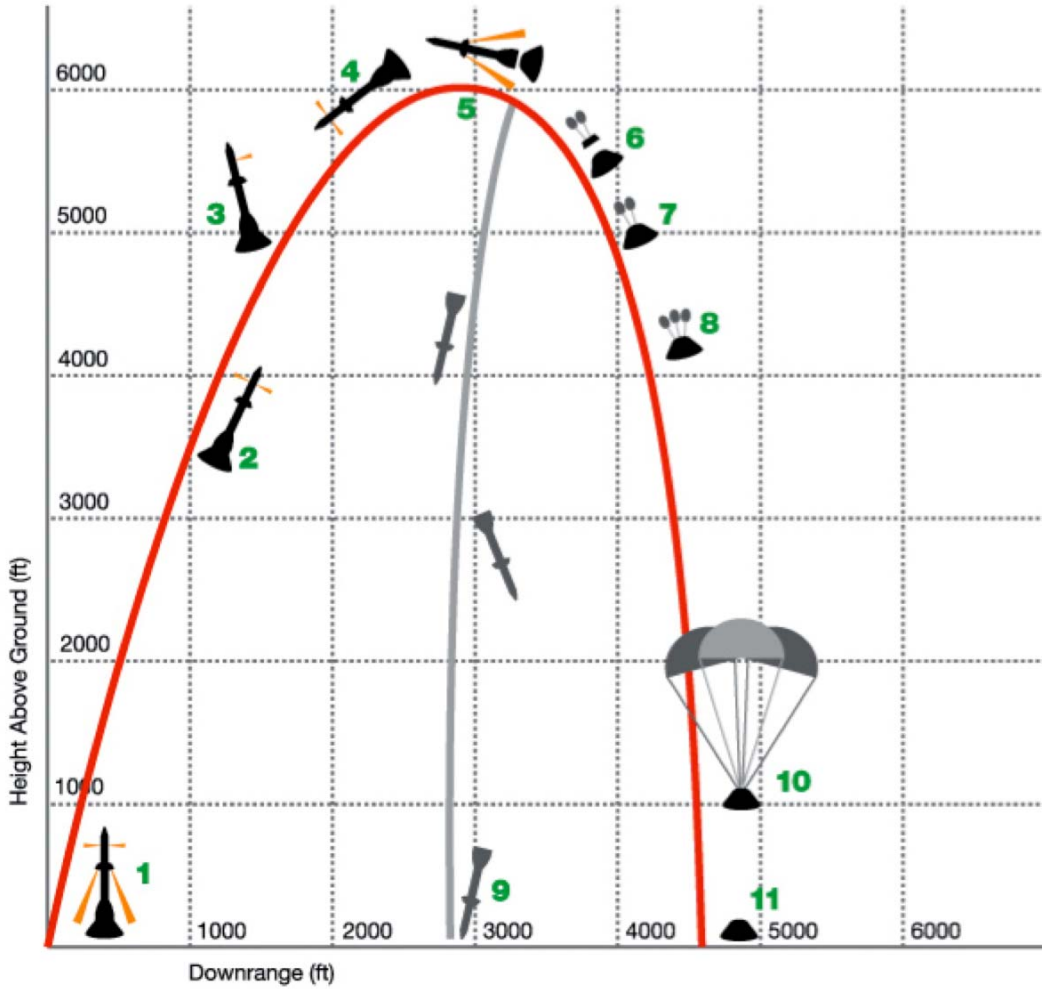
Crew Module touchdown about 4700 ft downrange

Mission timeline (continued):

- Forward bay cover jettison = 22 s
- Drogue mortar fire = 25 s
- Pilot mortar fire = 31 s
- Slow to 33 ft/s decent = 53 s
- Crew Module touchdown = 99 s

Pad Abort 1 Trajectory

ORION PA1



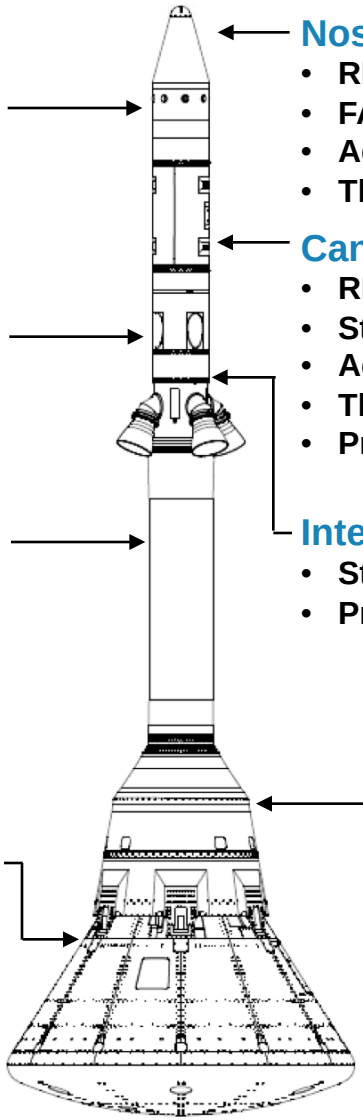
	Time	Event
1.	0 s	AM/ACM ignition
2.	7 s	AM burnout
3.	10 s	Begin re-orientation
4.	16 s	End re-orientation
5.	21 s	LAS Jettison
6.	22 s	FBC jettison
7.	25 s	Drogue mortar fire
8.	31 s	Pilot mortar fire
9.	49 s	LAS touchdown
10.	53 s	Reach 33 ft/sec descent rate
11.	99 s	CM touchdown

Day of Flight Timeline Highlights

- L-5days – Thermal Conditioning
- L-1day (0300-0800) – Range Lockdown Test
- L-1day (1000-1200) – PA1 Launch Crew Brief
- T-5:00:00 (0200) – Day-of-Launch Team pre-brief and MOF power-up
- T-3:30:00 (0330) – Mission Evaluation Room Staffing Complete
- T-3:00:00 (0400) – MOF Staffing Complete
- T-2:30:00 (0430) – LAS temp Predictions to MOF
- T-2:20:00 (0440) – Power on the Vehicle
- T-1:57:00 (0503) – Turn on Telemetry
- T-0:39:00 (0621) – Power on the ACM
- T-0:35:00 (0625) – Perform LAS Built-in-test
- T-0:07:00 (0653) - “Arm” the LAS motors
- T-0:01:50 (0658) – Enable the Abort Function
- T-0:00:00 (0700) – “Abort Execute” **Launch**
- T+0:01:39 – Crew Module Touchdown
- T+0:08:00 – Avionics automatic power down seq 1 (fire main chute cutters)
- T+0:14:00 - Avionics automatic power down seq 2 (All telemetry off)

Instrumentation Overview
(692 Total Sensors)

ORION PA1



Attitude Control Motor (ATK/Elkton)
- Strain Gauges
- Pressure Transducers
- Accelerometers
- Thermal

Jettison Motor (Aerojet)
- Strain Gauges
- Calorimeters
- Thermal

Abort Motor (ATK/Bacchus)
- Accelerometers
- Calorimeters
- Thermal
- Strain Gauges
- Pressure Transducers

Crew Module (LaRC/DFRC)
- Strain Gauges
- Pressure Transducers
- Accelerometers
- Thermal
- Voltage
- Cameras

Nose Cone Assembly (Orbital)
- RDAU
- FADS
- Accelerometers
- Thermal

Canard Interstage (Orbital)
- RDAU (2)
- Strain Gauges
- Accelerometers
- Thermal
- Pressure Transducers

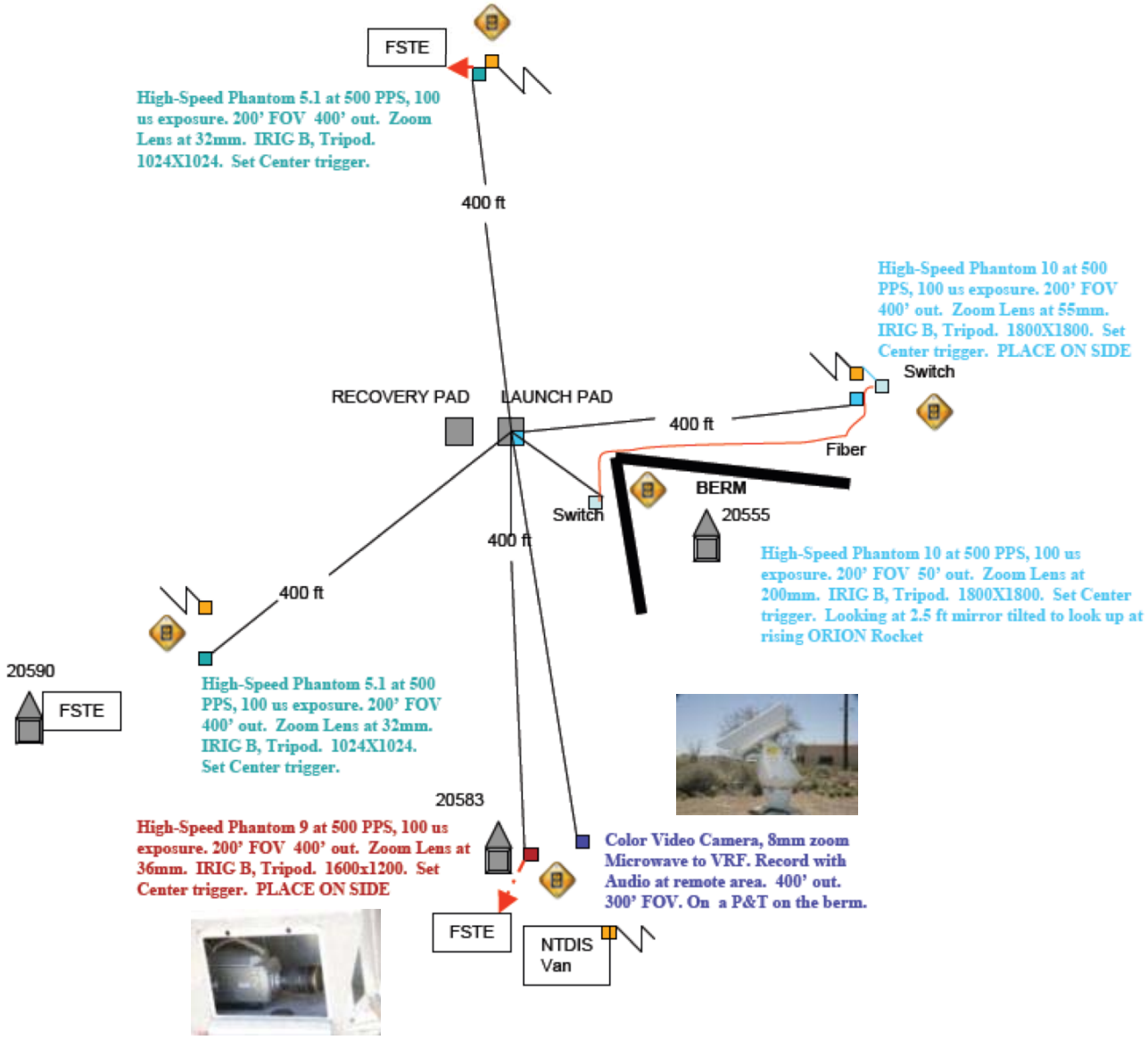
Interstage (Orbital)
- Strain Gauges
- Pressure Transducers

Optical Tracking
- 5 sites track CM
- 4 sites track LAS
- 1 site tracks FBC

Adapter Cone Assembly (Orbital)
- RDAU (2)
- Strain Gauges
- Accelerometers
- Thermal
- Pressure Transducers
- Calorimeters
- Microphones

WSMR Fixed Optics for PA-1

ORION PA1



The Extreme Abort Environment

Decibel comparison list

Whisper Quiet Library	30 dB
Normal conversation (3-5')	60-70 dB
City Traffic (inside car)	85 dB
Subway train at 200'	95 dB
Level at which sustained exposure may result in hearing loss	90-95 dB
Power mower at 3'	107 dB
Sandblasting, Loud Rock Concert	115 dB
Pain begins	125 dB
Pneumatic riveter at 4'	125 dB
Even short term exposure can cause permanent damage	
Loudest recommended exposure WITH hearing protection	140 dB
Jet engine at 100'Gun Blast	140 dB
Human throat is vibrating so hard it is almost impossible to swallow	153 db
Orion Launch Abort System Abort Motor	**160-170 db**
Death of hearing tissue	180 dB

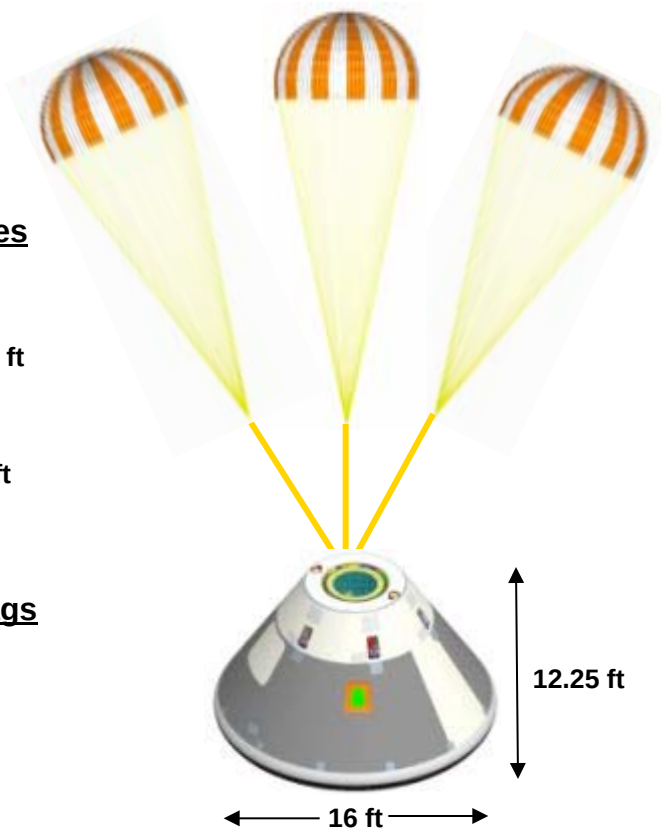
Recovery of Test Articles

ORION PA1

- **5 Landing Zones**
  - CM + 3 Main Chutes
  - 2 Drogue Chutes
  - 3 Pilot Chutes + attached D-Bags
  - FBC + attached parachutes (2)
  - LAS

CPAS Main Parachutes

270' – 400'
250 lbs each



Crew Module
(18,000 lbs)

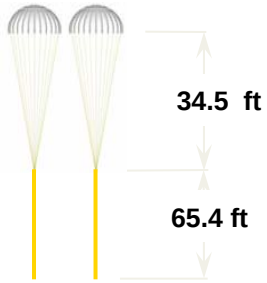
Launch Abort System (LAS)

FBC Parachutes

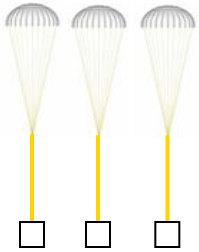
Forward Bay Cover (FBC)

8.5 ft diameter
450 lbs

Drogue Parachutes



Pilot Parachutes & D Bags



Electrical Ground Support Equipment

ORION PA1

MOF Overview

ORION PA1

Telemetry, video, timing distribution, and processing equipment racks (7)

LM Command, Control, and Monitoring System racks - not shown (3.5)

Video Monitors (4)

Workstation displays (21)

Intercom panels (18)

Integrated Launch Abort System at WSMR

ORION PA1

Adapter Cone Fit Check

ORION PA1

Final Prep for Phasing Test and Camera Mounts

ORION PA1

PA-1 Test Objectives Summary

Test data will have wide applicability to future launch vehicles to correlate models and refine analysis targets and will demonstrate the performance of three new types of motors, and innovations to lessen their weight and the need for ballast of this system

Summary Primary Test Objectives Demonstrate

- Performance of the Launch Abort System (LAS) and LAS/crew module interface
- Capability of the LAS to propel the module to a safe distance from a launch vehicle
- Stability and control characteristics of the LAV in the flight environment
- Determines the performance of the abort, jettison and attitude control motors
- Demonstrates abort event sequencing from abort initiation through LAS jettison
- Obtains LAS/crew module interface structural loads and external acoustics data

Secondary Test Objectives Demonstrate

- Parachute assembly system event sequencing
- Performance of the main parachute system

Many detailed primary and secondary objectives are documented for PA1

- These objectives will be studied and evaluated in detail in the months following the flight

Test Provides Valuable Development Experience

Combining direct observation, experience, and physical measurements with analysis leads to deeper understanding and insight to:

- Learn as much as possible, as early as possible in the product development cycle
- Anchor models and engineering tools with actual flight performance data
- Gain a deeper understanding of the vehicle
- Validate the initial vehicle design
- Acquire early design, manufacturing, integration and operations experience with a mature prototype vehicle
- Observe subtle and unexpected problems

Criteria for PA1 Success

Minimally Successful

Abort motor and attitude control motor ignite and LAV (launch abort vehicle) achieves lift off with both motors firing.

Successful

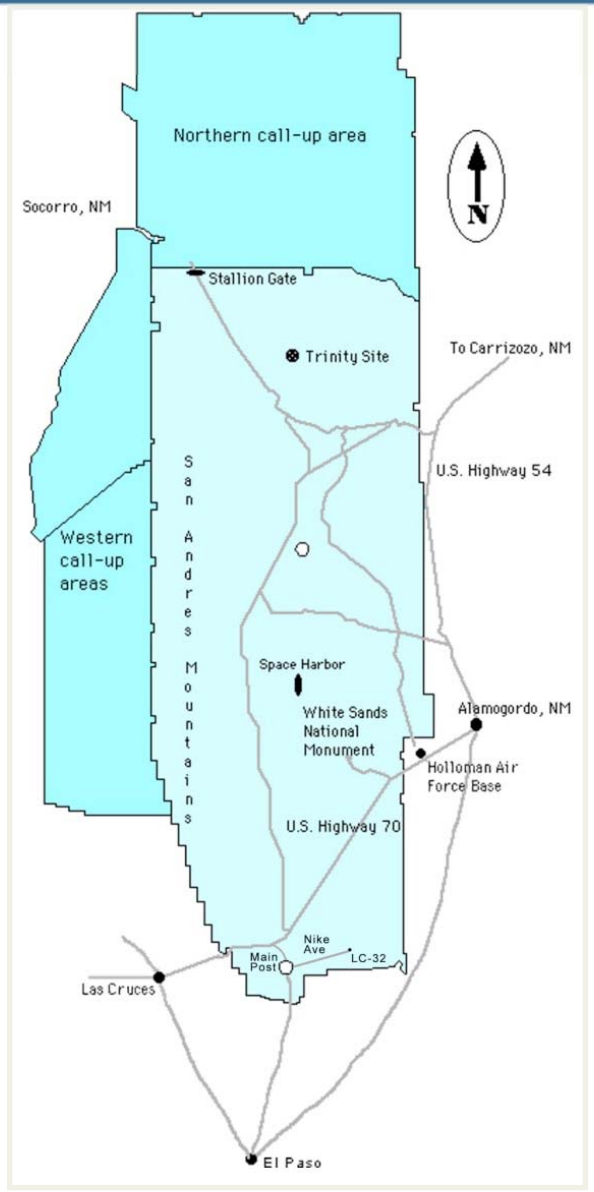
ACM continues firing and controlling as or nearly as expected and controls LAV downrange, conducts a successful reorientation, and delivers the entire LAV to the proper attitude for LAS jettison.

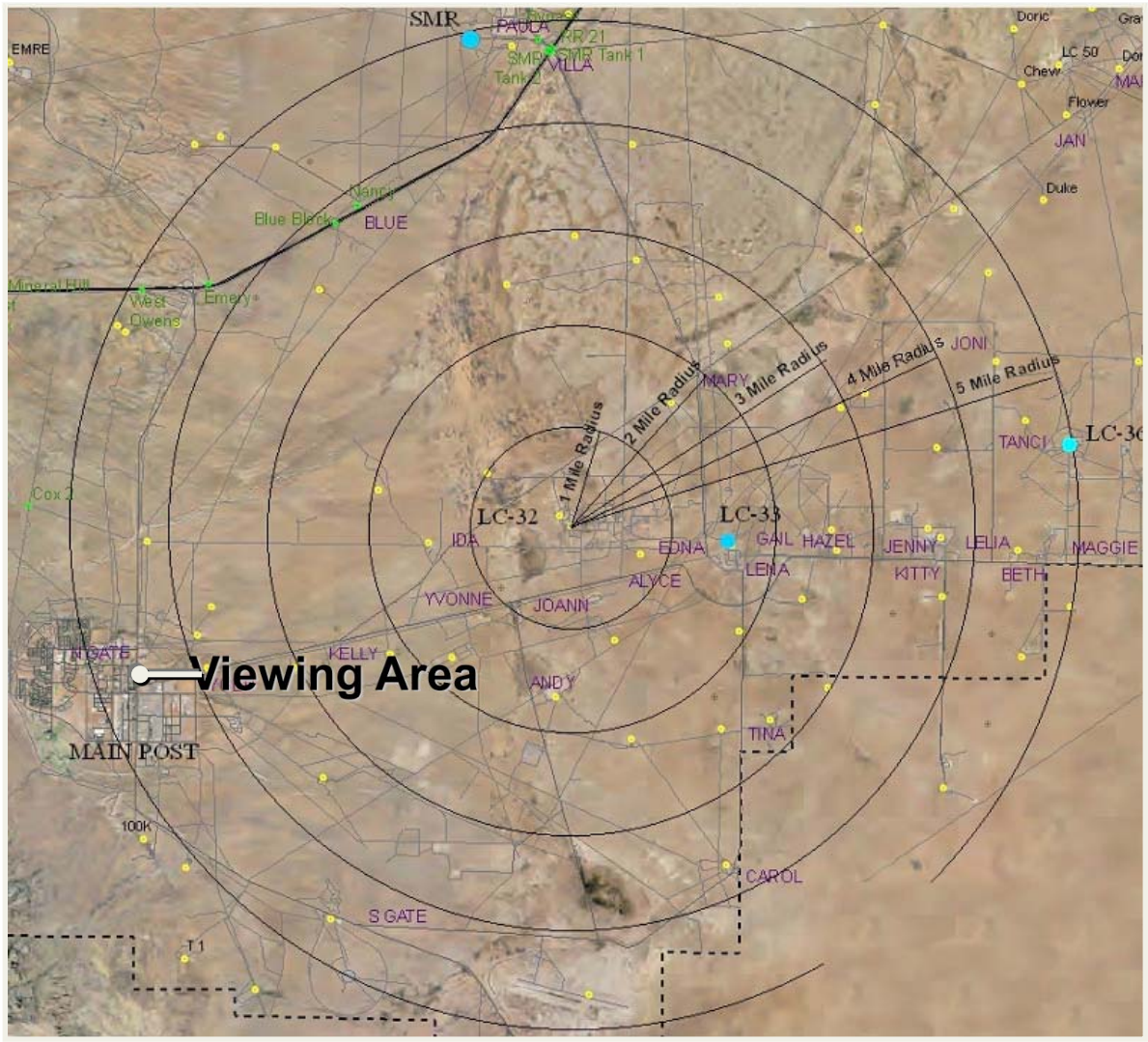
Fully Successful

All above objectives achieved plus deployment of forward bay cover, 2 drogues, 3 pilots and 3 main chutes extract and inflate to first stage.

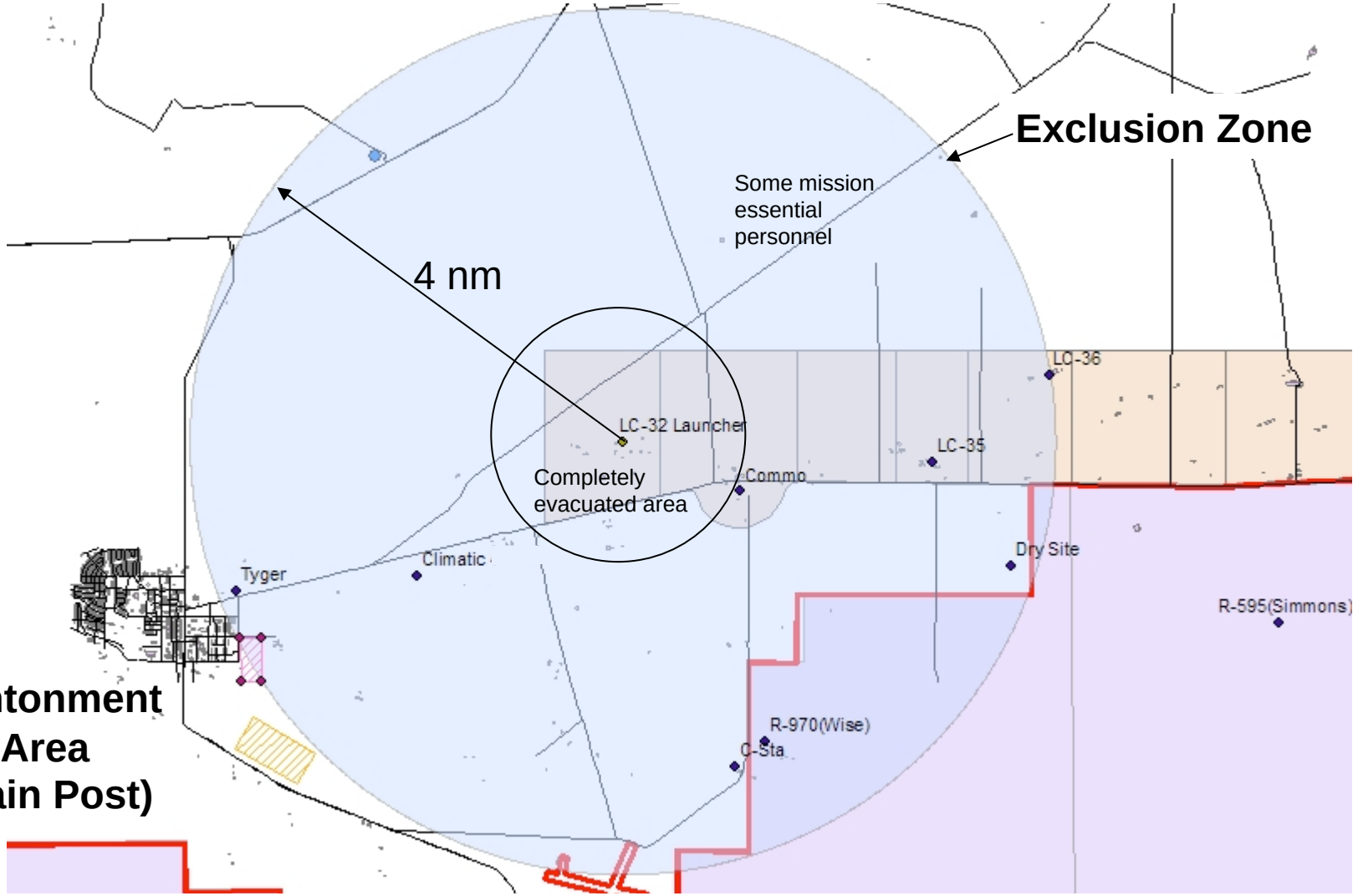
WSMR Layout and LC-32

ORION PA1



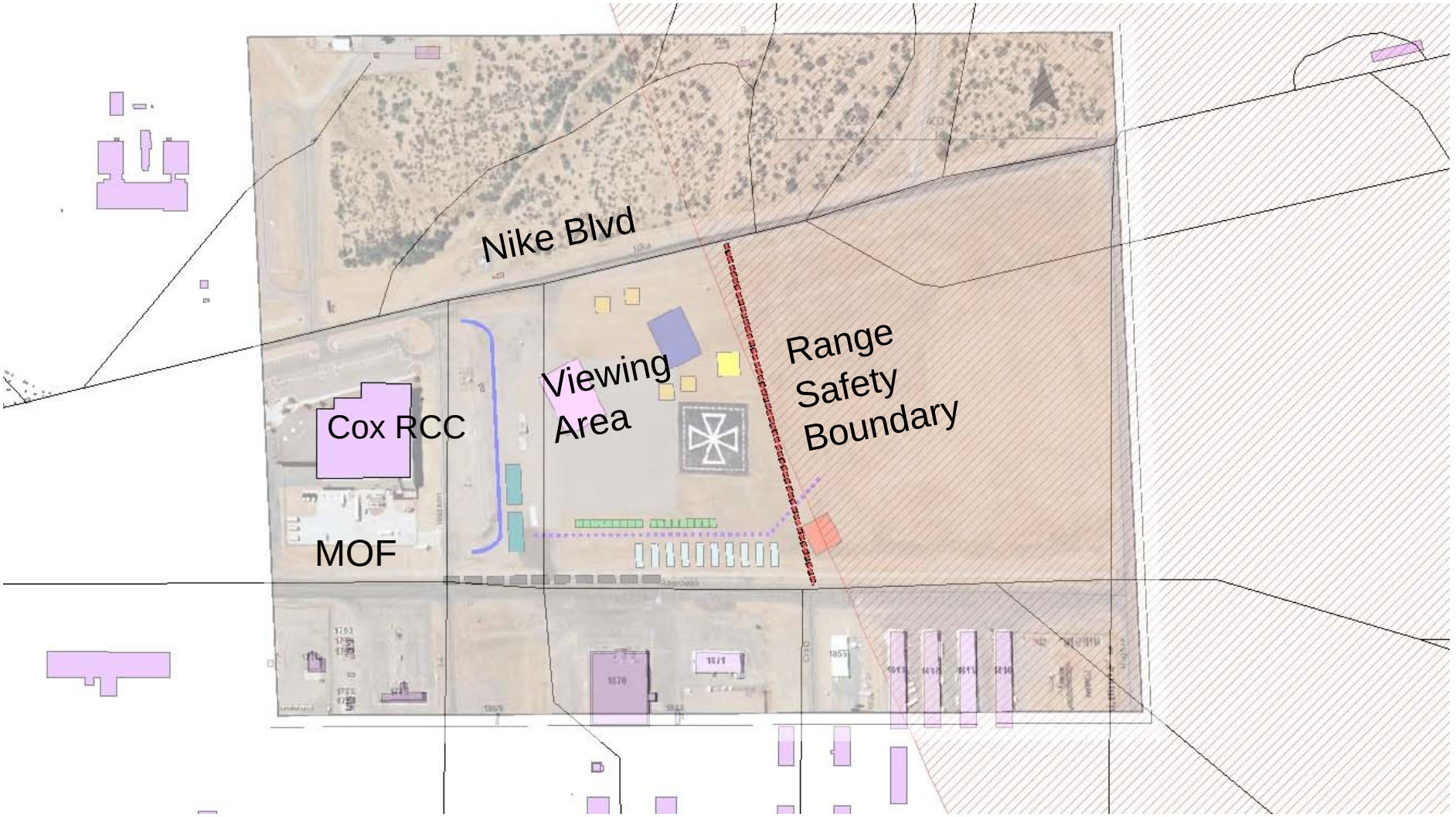


Evacuation Area



WSMR Viewing Site

ORION PA1



Range Safety Roadblocks for PA-1

- **WSMR PA-1 Flight Safety Operational Plan defines the roadblocks for PA-1**
  - Public highways - U.S. Highway 70 at RED and BLACK roadblocks (at St Augustine Pass to the west and 8 mi west of White Sands National Monument to the east)
  - Internal roadblocks as required to ensure the integrity of the evacuation area

NASA Center Involvement in Pad Abort-1

- **Johnson Space Center (TX)**
  - Orion and flight test office management
  - Parachute systems and LAS pyrotechnic nuts
  - Independent Technical Authority support
- **Dryden Flight Research Center (CA)**
  - Flight Test Article Development & Integration
  - Lead Abort Flight Test Integration & Operation
  - Safety and Quality Integration
  - Development Flight Instrumentation
- **Langley Research Center (VA)**
  - Primary Crew Module and Separation Ring Structure, All heavy ground support equipment
  - Lead for LAS integration and management
- **Marshall Space Flight Center (AL)**
  - LAS systems engineering and integration support
  - LAS propulsion support
  - LAS safety support
- **White Sands Test Facility (NM)**
  - Operations (including crane operators and facilities) and Safety support
  - Design team support and aircraft technician support

PA1 Participants

ORION PA1

Dryden Flight Research Center (CA)
- DFI, operations, vehicle integration

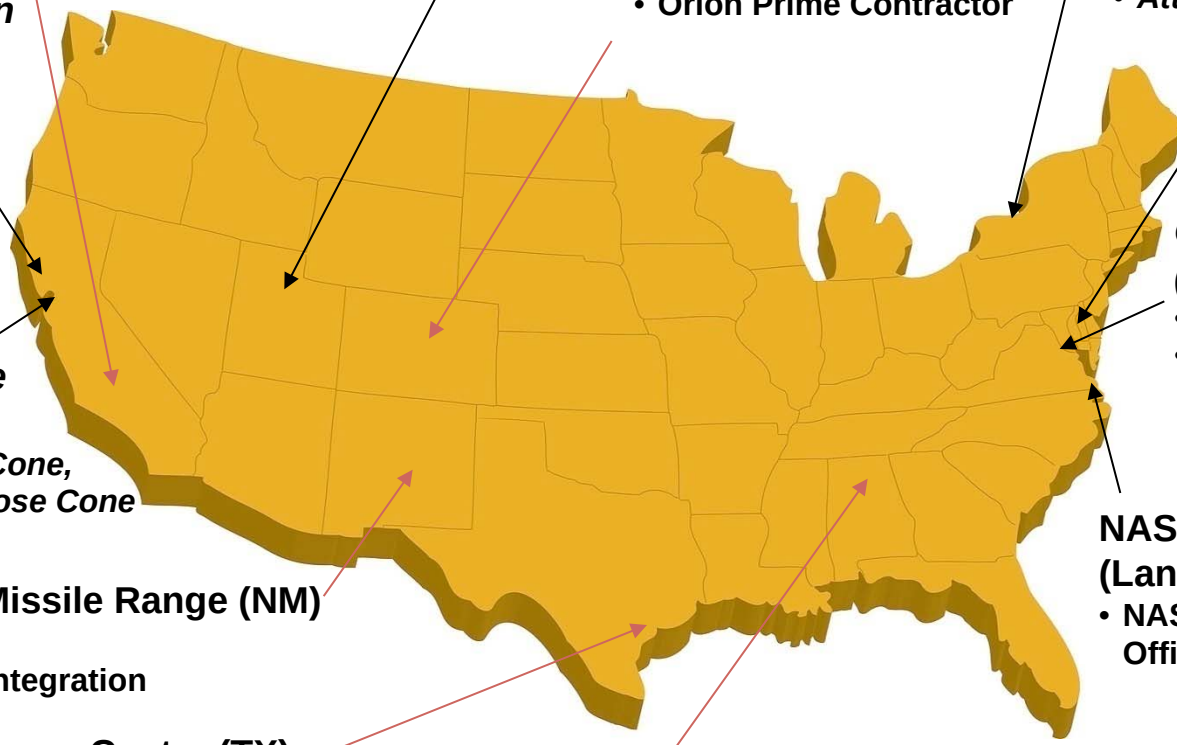
ATK (Magna, UT)
- *Abort Motor*

Moog (East Aurora, NY)
- *VCS*

Lockheed Martin (CO)
- LM LAS IPT
- Orion Prime Contractor

ATK (Elkton, MD)
- *Attitude Control Motor*

Aerojet Corporation (Sacramento, CA)
- *Jettison Motor*



Orbital Sciences (Dulles, VA)
- *Harness*
- *Orbital Program Office*

Applied Aerospace (Stockton, CA)
- *Structure: Adapter Cone, Interstage, Canard, Nose Cone*

NASA/LaRC (Langley, VA)
- NASA LAS Program Office

White Sand Missile Range (NM)
- Flight Tests
- Assembly & Integration

Johnson Space Center (TX)
- Orion Program Office
- Flight Test Office

Marshall Space Flight Center (AL)
- Propulsion

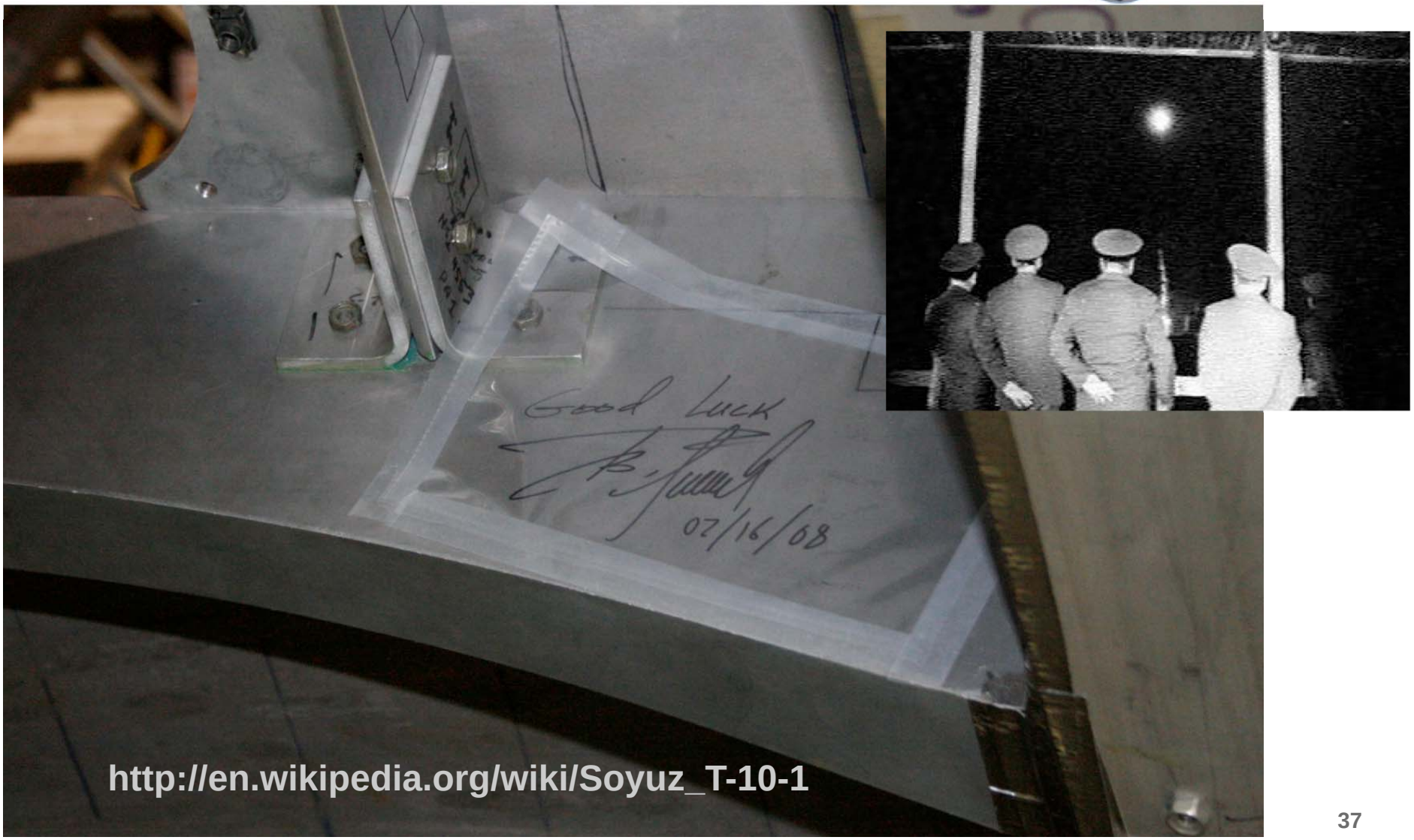
Summary

Pad Abort-1 is first in a sequence of planned Orion abort flight tests that are critical to the human rating of any crewed spacecraft

- **New technologies developed**
  - The Pad Abort 1 flight test will demonstrate in flight three new types of rocket motors - at full scale - for the first time
  - These motors demonstrate a lighter, more agile system than previously possible, across a wider range of flight conditions
- **Data to be obtained and its uses going forward**
  - The data from this flight will provide designers of future human spaceflight systems with data on launch abort environments, crew capsules, parachute systems, and ground operations, and document capabilities as well as problems that were encountered and preliminary solutions.
  - 100% of flight data is telemetered on this vehicle, and it is recorded in 2 redundant solid state recorders onboard.
- **Expectations**
  - We have reduced risk as much as feasible on this test
  - This is the first full-scale flight of a fully integrated abort design and carries more risk than a crewed flight, and unknowns are significantly more in first flight tests
  - The PA-1 test hardware has no planned future use, any consequent CM damage has no impact to abort technology or flight capsule development
  - Tests are not always successful, but we always learn. We are at the cutting edge of technology and learn from every outcome.

Russian Pad Abort
September 1983 - Vladimir Titov

ORION PA1



http://en.wikipedia.org/wiki/Soyuz_T-10-1